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辽西下白垩统九佛堂组尾羽龙类一新属[1)]

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摘要:记述了一件采自辽西热河群九佛堂组一新的窃蛋龙类:义县似尾羽龙(*Similicaudipteryx yixianensis* gen. et sp. nov.),并依据其和尾羽龙属的相似特征,及其匕首状的尾综骨,肠骨、蹠骨和脚趾的形态等将其归入窃蛋龙类的尾羽龙科,但其所具有的一些特征也不同于该科已建立的尾羽龙属,如尾综骨的形态和较大的个体等。该化石具有许多典型的窃蛋龙类的特征,如短尾、较短的前肢等,有别于其他窃蛋龙类的特征还包括耻骨和肠骨的长度比为1.46,背椎上发育2个大而深的椎体下突、背椎侧部具孔等。义县似尾羽龙是又一类具有真正尾综骨的恐龙,表明尾综骨这一曾经被认为是鸟类特有的结构可能是在恐龙中独自演化的。它具有一些进步的特征如具尾综骨等,但同时也具有一些原始的特征如5个愈合的荐椎,耻骨联合长,表明在窃蛋龙类中存在着特征的镶嵌进化现象。似尾羽龙与驰龙类、其他窃蛋龙类等恐龙一样,脚趾并没有对握,已有的证据说明完全的对握目前还只是出现于鸟类中。根据其短尾、中部收缩的趾骨和灵巧的身体等都表明它是一类适于快速奔跑的动物。目前为止,已知的尾羽龙类化石均发现于北票四合屯地区的义县组下部尖山沟层(段),距今约125 Ma。新标本发现于义县西二虎桥地点,属于九佛堂组,距今约120 Ma,这也是迄今为止在九佛堂组发现的惟一一件尾羽龙类化石,对研究早白垩世窃蛋龙类的演化和热河生物群恐龙组合的特征具有重要的意义。

关键词:辽西,白垩纪,九佛堂组,尾羽龙
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A NEW GENUS AND SPECIES OF CAUDIPTERID DINOSAUR FROM THE LOWER CRETACEOUS JIUFOTANG FORMATION OF WESTERN LIAONING, CHINA

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Abstract A new oviraptorosaur, *Similicaudipteryx yixianensis* gen. et sp. nov. is described from the Jiufotang Formation (120 Ma) of the Jehol Group in western Liaoning, China, which is referred to the Caudipteridae based on a dagger-like pygostyle and the shape of the ilium that are most similar to those

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of *Caudipteryx*. It differs from other oviraptorosaurids in that the ratio of pubis to ilium length is 1.46 and the presence of two large and deep hypapophyses on dorsal vertebrae. The known caudipterids have previously been found only from the Jianshangou Member of the Yixian Formation (125 Ma) of the Sihetun area in Liaoning Province. *S. yixianensis* represents the first caudipterid dinosaur from the Jiufotang Formation. The new discovery provides more information for the discussion of the evolution of oviraptorids during the Early Cretaceous and adds to the dinosaur assemblage of the Jehol Biota.
Key words western Liaoning, Early Cretaceous, Jiufotang Formation, Caudipteridae

Till now, caudipterid dinosaurs have only been found from the lower Yixian Formation (125 Ma) near the famous Sihetun locality in Beipiao, western Liaoning of northeast China (Ji et al., 1998; Zhou and Wang, 2000; Zhou et al., 2000). The present note is a description of a new genus and species of caudipterid, *Similicaudipteryx yixianensis* gen. et sp. nov. The specimen (IVPP V 12556) here described was found from the Jiufotang Formation (120 Ma) in Xierhuqiao site, Yixian County, western Liaoning. It is preserved in grayish shale. The first pygostyle in non-avian theropods was recently reported in *Nomingia gobiensis* (Barsbold et al., 2000). Although V 12556 is an incomplete individual (the skull lost) with nearly complete hindlimbs and pelves, it displays a number of postcranial characters closer to more typical oviraptorosaurs, such as a shorter tail (the estimated number of the caudals is 23-26), and a shorter forelimb relative to the hindlimb. Most characters such as the ilium and metatarsals are characteristic of caudipterids, but the other characters on this specimen are different from the two known caudipterid species *Caudipteryx zoui* and *C. dongi*. The new caudipterid also represents non-avian theropod with a pygostyle, a feature typical of birds.

1 Systematic paleontology

Theropoda Marsh, 1881
Maniraptora Gauthier, 1986
Caudipteridae Zhou & Wang, 2000
***Similicaudipteryx* gen. nov.**

Type species *Similicaudipteryx yixianensis* gen. et sp. nov. (Figs. 1-7)

Generic diagnosis As for the type and only known species.

Holotype An incomplete individual with nearly complete hindlimbs and pelves (Institute of Vertebrate Paleontology and Paleoanthropology, IVPP V 12556).

Etymology The generic name refers to its similarity to *Caudipteryx*; the specific name refers to the fossil locality, Yixian of Liaoning Province.

Locality and horizon Xierhuqiao, Qianyang, Yixian County, Jinzhou City, Liaoning Province, northeast China; Jiufotang Formation, Early Cretaceous (Aptian) (Wang et al., 2000; He et al., 2004).

Diagnosis An oviraptorosaur displaying the following characters: a dagger-like pygostyle; the shape of the ilium is most similar to the caudipterids and different from other oviraptorosaurids; the ratio of pubis to ilium length is 1.46; two large and deep hypapophyses on dorsal vertebrae.

2 Anatomical descriptions

The present anatomical description focuses on the most novel information preserved in this specimen. The skull was not preserved, but most postcranial bones were preserved.

Cervical series The cervicals were not completely preserved (Fig. 2). There are 6 amphicoelous cervical vertebrae preserved near the dorsal region, which are tightly articulated to

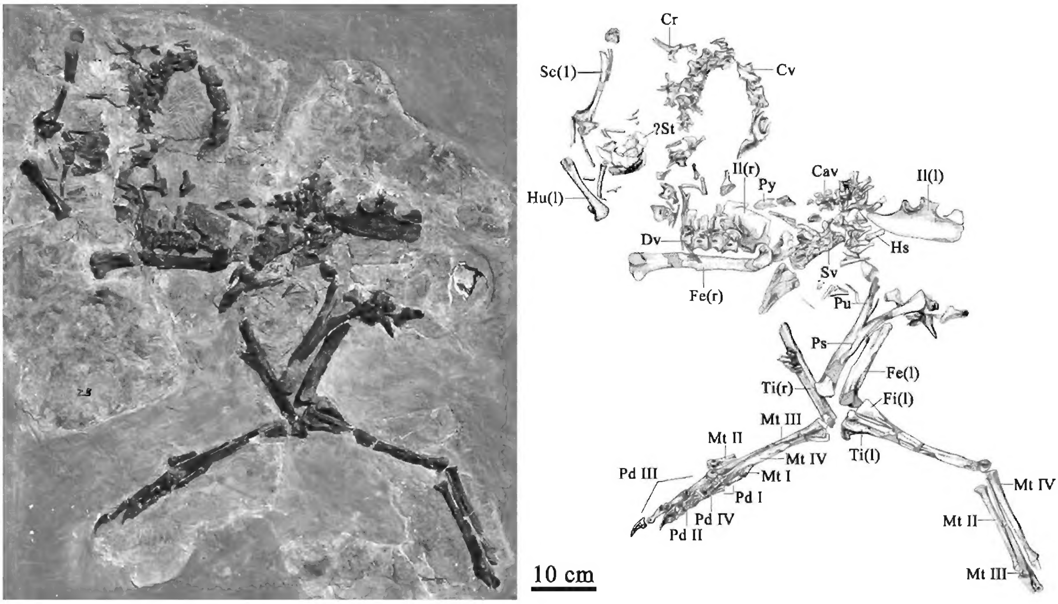

Fig. 1 Holotype of *Similicaudipteryx yixianensis* gen. et sp. nov. (IVPP V 12556)
Abbreviations: Cav. caudal vertebra; Cr. cervical rib; Cv. cervical vertebra; Dv. dorsal vertebra; Fe (l). left femur; Fe (r). right femur; Fi (l). left fibula; Hs. haemal spine; Hu (l). left humerus; Il (l). left ilium; Il (r). right ilium; Mt I-IV. metatarsals I-IV; Pd I-IV. pedal digits I-IV; Py. pygostyle; Ps. pubic symphysis; Pu. pubis; Sc (l). left scapula; St. sternum; Sv. sacral vertebra; Ti (l). left tibia; Ti (r). right tibia

each other, and the last cervical is articulated with the first dorsal centrum (The first dorsal has large and deep hypapophysis). The number of cervical vertebrae cannot be determined because the anterior cervicals were lost. The last cervical centrum bears a pair of pleurocoels, which are situated close to the upper portion of the centrum in lateral view. The neural spine was broken, but it appears to be low and thin. The anterior cervical centra are markedly higher than wide, the height of cervical centra decreases posteriorly and the height of the last cervical is almost equal to its width. The length of the cervical centrum becomes shorter posteriorly in the series. Anterior cervical centrae extend beyond the posterior limit of the neural arch. The cervical has an elongated postzygapophysis that is longer than the prezygapophysis. The length of the postzygapophysis and prezygapophysis decreases posteriorly in the series. The postzygapophysis markedly extends beyond the centra. Epipophyses of cervical vertebrae are placed distally on the postzygapophysis. In the last five cervicals, the neural arches have a X-shaped appearance in dorsal view. Some separated ribs near the cervical region are identified to be the cervical rib.

Dorsal series There were 14 dorsals preserved (Figs. 2-3). The anterior dorsals include 6 well-articulated centra; there are 4 dorsal centra near the sacral region. The number of dorsals is difficult to confirm. The first and second dorsals have large and deep hypapophysis, the third dorsal was so broken that it is hard to determine if it has a hypapophysis but the fourth does not have a hypapophysis. In V 12556, the hypapophysis is large and deep; in *Ingenia*, the hypapophysis is week; in dromaeosaurs and troodontids, the hypapophysis is large. The anterior dorsal centra are slightly higher than wide; the posterior dorsal centrae are markedly wider than high. Each dorsal bears a pair of deep pleurcoels. Both the prezygapophyses and postzygapophyses are short. The four dorsal centra near the sacral region have high and wide neural spines, which are nearly twice as long as the centra. The suture between the neural arches and

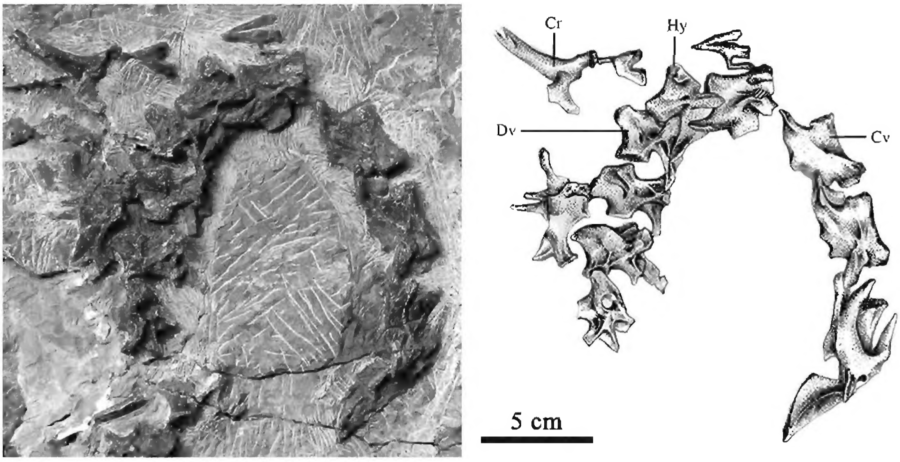

Fig. 2　Cervical and dorsal vertebra of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Cr. cervical rib; Cv. cervical vertebra; Dv. dosal vertebra; Hy. hypapophysis

the centra of dorsals are absent, indicating that this specimen probably represents a mature individual.

Sacral　The sacrum is composed of five co-ossified vertebrae, measuring 85 mm in total length. The ventral margin is flat (Fig. 3).

Caudal series　There are 23 caudal vertebrae preserved. If the lengths of the missing segments of the tail are accounted for, there were fewer than 26 caudals. The tail was not preserved as a straight rod as in dromaeosaurs; on the contrary, the tail is curved as in *Caudipteryx*. The caudals are so broken that there is not a complete caudal centrum preserved. In general, the centrum is short, wider than high. The ventral margin of the centrum is flat. The last two caudals are co-ossified into a dagger-like pygostyle; it is a relatively straight, tapering co-ossified mass (Fig. 3). Caudals do not become longer posteriorly, as they do in most non-avian theropods and *Archaeopteryx*. In the last 5 fused caudals, the arches cannot be distinguished, and only the massive crest with a sharp dorsal margin projects above the centra. The length of the parapophysis is longer than the centrum. There were 6 chevrons preserved. The chevrons are anteroposteriorly broad and dorsoventrally elongated. The anterior chevrons are longer and larger than posterior ones. The distal chevrons are rectangular in shape.

Shoulder girdle and forelimb　Only part of the left scapula is preserved and articulated with the coracoid (Fig. 4). It is a slender bone; the width of the proximal end is almost equal to that of the distal end. The middle of the scapula is slender. The proximal end of the left coracoid is preserved. It has a coracoidal foramen, situated on the anterior part of the coracoid. The left humerus was preserved, with the proximal end missing. The humerus is estimated to be longer than the ulna and radius as in *Caudipteryx*, *Archaeopteryx*, *Confuciusornis* and theropod dinosaurs generally. Both of the left ulna and the left radius were incompletely preserved. The ulna is slightly bow-shaped and the radius is relatively straight. Some broken bones near the left scapula may be the sternum.

Pelvic girdle　Pelvic elements are unfused, as in all non-avian theropods (except some ceratosaurs). The left ilium is completely preserved (Fig. 5). The length of the ilium is longer than the fused sacrum. The postacetabular portion of the ilium is longer than the preacetabular portion; in dromaeosaurids and *Caudipteryx* the preacetabular portion of the ilium is as long as the postacetabular portion, but in early birds the preacetabular portion is longer than the postacetabular portion. The ilium has a moderately deep preacetabular portion that tapers anteroven-

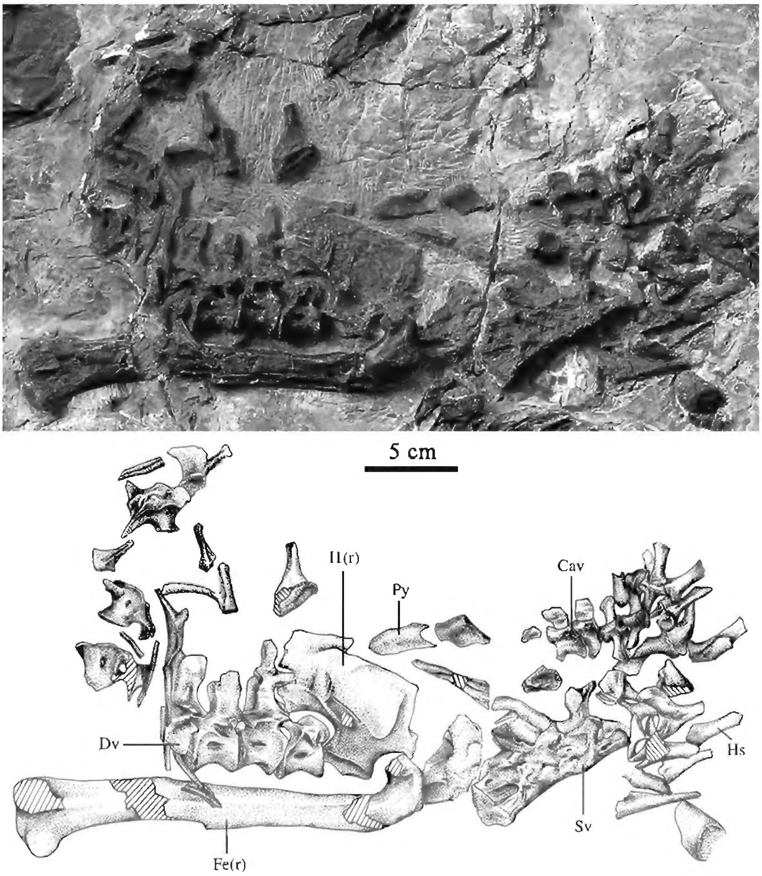

Fig. 3 Dorsal and caudal vertebra of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Cav. caudal vertebra; Dv. dorsal vertebra; Fe(r). right femur; Hs. haemal spine; Il (r). right ilium; Py. pygostyle; Sv. sacral vertebra

trally, but does not extend as far ventrally as the pubic peduncle. The postacetabular portion tapers posteriorly as in *Deinonychus* and other dromaeosaurids and early birds. The acetabulum is large; the ratio of acetabulum to ilium length is about 0.23. The pubic peduncle is much deeper than the ischiadic peduncle as in *Caudipteryx*, dromaeosaurids and birds; in oviraptorids the pubic peduncle is nearly as deep as the ischiadic peduncle. The pubic peduncle forms the anterior wall of the acetabulum; in birds it forms the anterior part of the ventral wall of the acetabulum (Zhou et al., 2000). The pubis and the pubic symphysis are long, and the ratio of the pubic symphysis to pubis length is 0.57. A separate bone near the pubis is probably the ischium. It has a triangular shaft.

Hindlimb The hindlimb is almost completely preserved and well articulated (Fig. 6). The femur is moderately curved. The right femur is the most completely preserved and the proximal end of the left femur is missing. The femoral head is not large, and it projects only slightly from the femur. The femur is slightly shorter than the fibula and tibia, and the ratio of femur to tibia length is 0.92. The tibia is slightly longer than the fibula.

The right and left metatarsals are preserved, but only the left metatarsals are well preserved (Fig. 7). The fifth metatarsal is missing on both sides. The three main metatarsals (II-IV) are not fused, as in most non-avian theropods. Of the preserved metatarsals, the third is the lon-

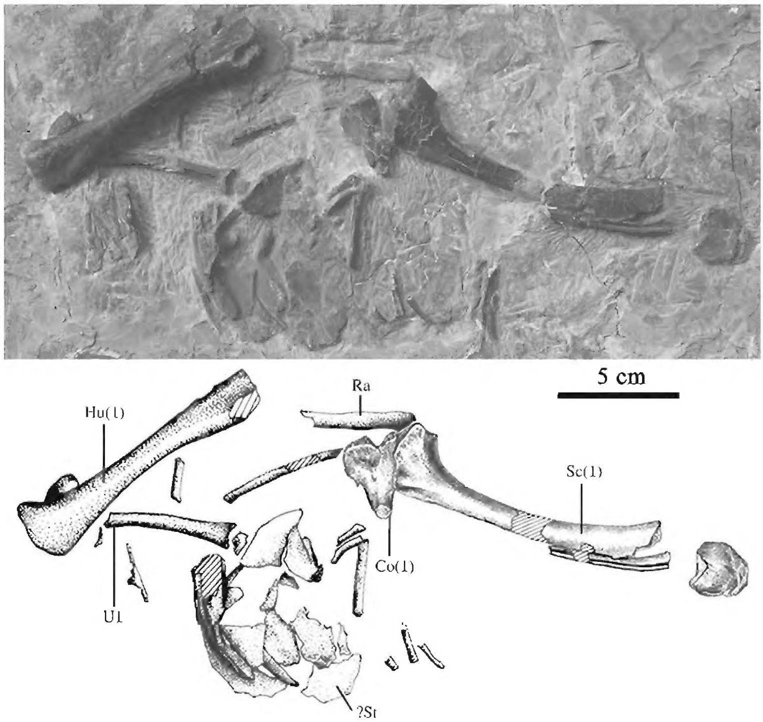

Fig. 4 Shoulder girdle and forelimb of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Co(l). left coracoid; Hu(l). left humerus; Ra. radius; Sc(l). left scapula; ?St. ?sternum; Ul. ulna

gest; the second is slightly shorter than the fourth, the ratio of the fourth to third length is 0.84. The second metatarsal is as wide as the fourth metatarsal. The mid-shaft of the third metatarsal is laterally compressed and appears much narrower than the second and fourth metatarsals in anteroposterior view.

The proximal end of the first metatarsal is positioned about one third of the way up the second metatarsal from the distal end. It is articulated with the posteromedial side of the second metatarsal. It is different from the usually "J"-shaped first metatarsal in birds. It is symmetric and has a pointed proximal end; the distal half is constricted with a well-developed ball-shaped articulating surface for the first phalanx.

Among the four pedal digits the third is the longest, and the ratio of the third digit to third metatarsal length is 0.79. The first phalanx is the longest, as is typical of theropods and many birds. The second phalanx is shorter and the third phalanx is the shortest among the phalanges of the third digit. The ungual is slightly curved; the ungual of the second pedal digit is about as long as the ungual of the third pedal digit, the ungual of the first is about as long as the ungual of the fourth, the second and third unguals are clearly longer than the other unguals. The second pedal digit is as robust as the third but is much shorter; the first phalanx of the second digit is shorter than that of the third digit and much longer than the second phalanx as is typical of cursorial animals. The ungual is curved and shorter than the second phalanx. The fourth digit is shorter than the second digit; the first phalanx of the fourth digit is much longer than the other phalanges; the fourth phalanx is the shortest among the phalanges of the fourth digit. The first phalanx of the first digit is shorter than all the phalanges of the second and third digits; distally it does not extend to the distal end of the second metatarsal (Table 1).

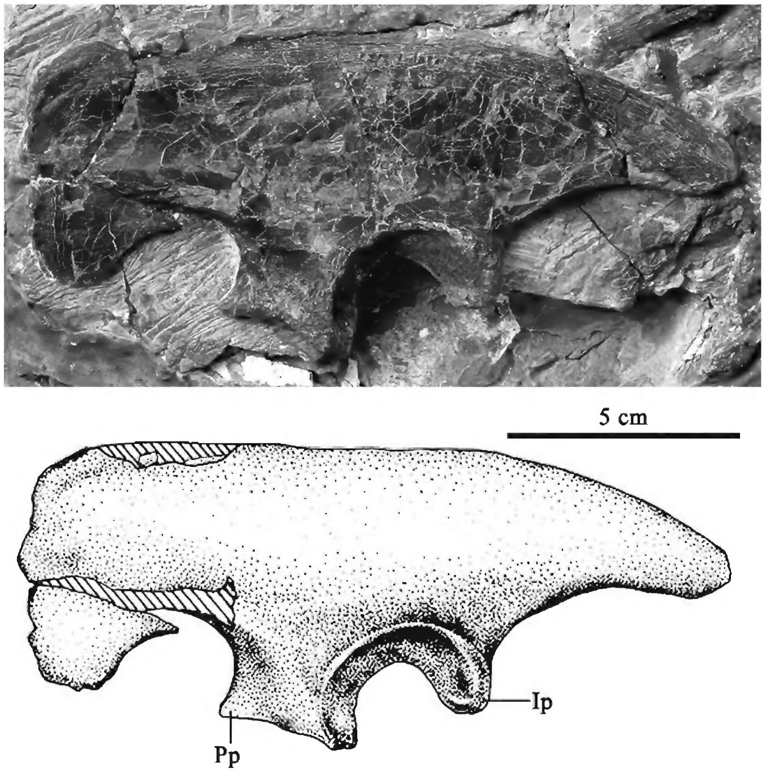

Fig. 5 Left ilium of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Ip. ischiadic peduncle; Pp. pubic peduncle, left side in lateral view

Table 1 Selected measurements of the holotype of *Similicaudipteryx yixianensis* gen. et sp. nov. (IVPP V 12556) (mm)

Pubis length	223*	Metatarsal IV length	153
Diameter of acetabulum between peduncles	35	First phalanx of pedal digit I length	28
Pubic symphysis length	128*	Second phalanx of pedal digit I length	23
Humerus length	130*	First phalanx of pedal digit II length	43*
Humerus mid-shaft width	11	Second phalanx of pedal digit II length	39
Ilium length	153	Third phalanx of pedal digit II length	33
Ilium height	69	First phalanx of pedal digit III length	46
Leg total length	853*	Second phalanx of pedal digit III length	34
Right femur length	220*	Third phalanx of pedal digit III length	32
Femur mid-shaft width	20*	Fourth phalanx of pedal digit III length	34
Tibia length	240*	First phalanx of pedal digit IV length	30
Fibula length	223*	Second phalanx of pedal digit IV length	23
Metatarsal I length	25	Third phalanx of pedal digit IV length	18
Metatarsal II length	144	Fourth phalanx of pedal digit IV length	21
Metatarsal III length	183*	Fifth phalanx of pedal digit IV length	20

* indicates estimated value.

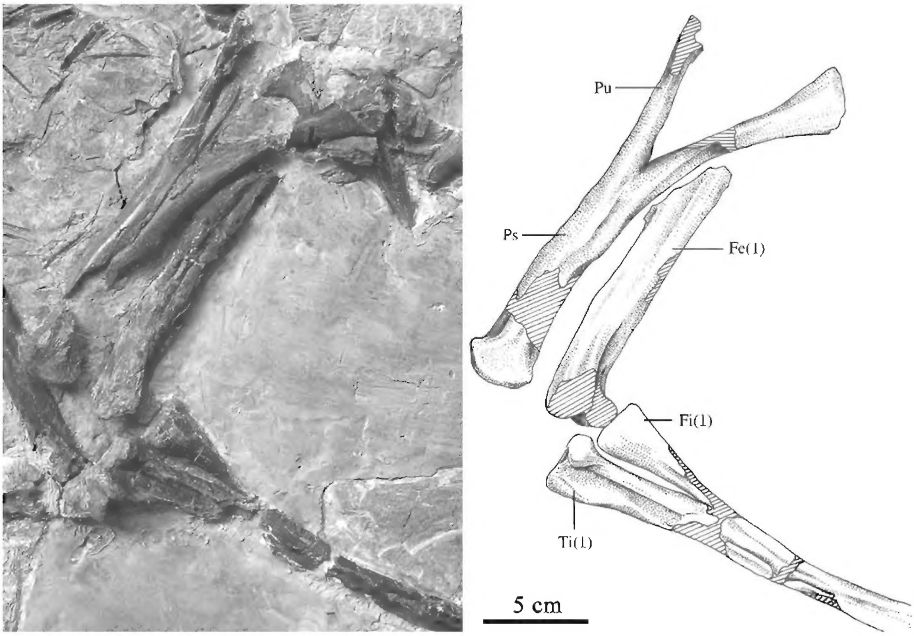

Fig. 6　Hindlimb of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Fe(l). left femur; Fi(l). left fibula; Ps. pubic symphysis; Pu. pubis; Ti(l). left tibia

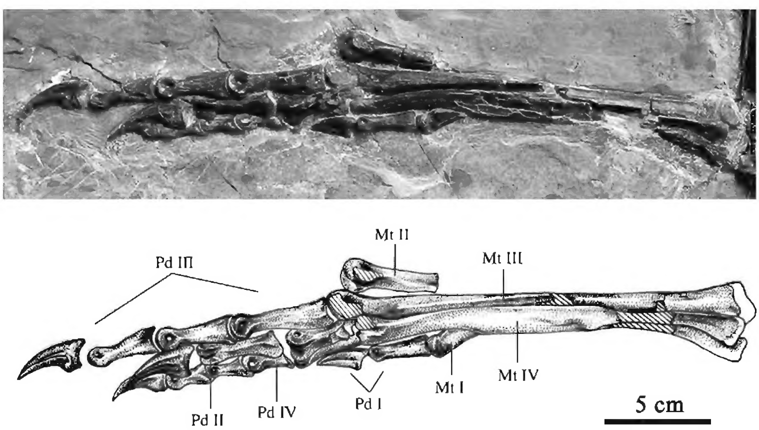

Fig. 7　Left foot of *Similicaudipteryx yixianensis* (IVPP V 12556)
Abbreviations: Mt I–IV. metatarsals I–IV; Pd I–IV. pedal digits I–IV

3　Discussions and conclusions

Oviraptorosauria is a Cretaceous group of cursorial dinosaurs, mostly of small size, with lightly built skeletons and raptorial hands and slender hindlimbs that display most common theropod characters. The Oviraptorosauria, in general, is diagnosed on the cranial characters such as extensively fenestrated mandible with a medial process on the articular; dentary with two long caudal processes, the ventral process bordering the mandibular fenestra; very shallow splenial; prearticular that extends rostrally along more than half the length of the mandible (Barsbold and

Osmólska, 1990). The vertebral column in the Oviraptorosauria is basically similar to that of most other coelurosaurian theropods, except for the tail.

In *Similicaudipteryx*, the tail comprises at most 26 caudals estimated from the specimen. The number of caudals is at most 30 in other oviraptorids, with the possible exception of a juvenile specimen of *Conchoraptor gracilis* Barsbold, 1986, which seems to have 32 caudals. The shortest known tail in Oviraptorosauria is that of *Caudipteryx zoui* (Ji et al., 1998), which has 22 caudals. Although the forelimb was not well preserved, the forelimb of *Similicaudipteryx* is short relative to the hindlimb. It also has prominent cervicodorsal hypapophyses. Based on the above characters there is no doubt that *Similicaudipteryx* exhibits some oviraptorosaurian synapomorphies and for this reason it is assigned here to Oviraptorosauria.

The shape of the ilium in *Similicaudipteryx* is most similar to the caudipterids and is different from other oviraptorosaurids such as deep peduncle than the ischiadic peduncle; moderately deep preacetabular portion that tapers anteroventrally, and so on (Fig. 8). The metatarsals (the fifth metatarsal is missing in *Similicaudipteryx*) are also similar to the caudipterids on the following characters: the three main metatarsals are not fused; of the preserved metatarsals, the third is the longest; the second is slightly shorter than the fourth; the second metatarsal is as wide as the fourth metatarsal; the mid-shaft of the third metatarsal is laterally compressed and appears much narrower than the second and fourth metatarsals in anteroposterior view; the proximal end of the first metatarsal is positioned about one third of the way up the second metatarsal from the distal end. The mid-shaft of the third metatarsal is significantly mediolaterally compressed; in oviraptorids, the third metatarsal narrows only slightly at the proximal end; in theropods such as many ornithomimids (Barsbold and Osmólska 1990), elmisaurids (Currie, 1990) and troodontids (Osmólska and Barsbold, 1990) the third metatarsal tapers proximally; in most birds and some dromaeosaurids (Norell and Makovicky, 1997) the width of the third metatarsal does not change much from the proximal to the distal end (Chiappe, 1996). The fourth digit is shorter than the second digit; the first phalanx of the fourth digit is much longer than the other phalanges; the fourth phalanx is the shortest among the phalanges of the fourth digit. In *Deinonychus*, troodontids, *Archaeopteryx* and *Confuciusornis* (Ostrom, 1976; Hou et al., 1995; Martin et al., 1998), the fourth pedal digit is longer than the second digit. The first phalanx of the first pedal digit is shorter than all the phalanges of the second and third digits; distally it does not extend to the distal end of the second metatarsal as in oviraptorids (Clark et al., 1999) and *Deinonychus* (Ostrom, 1990), while in anther dromaeosaur (Norell and Makovicky, 1997) it extends past the distal end of the second metatarsal distally, and in birds it extends even further distally.

But other characters on this specimen are different from the two known caudipterids *C. zoui* and *C. dongi*. In *Similicaudipteryx*, the last 5 caudals are co-ossified into a dagger-like pygostyle, in both *C. zoui* and *C. dongi* the distal caudal vertebrae are not fused. The last cervical and all the preserved dorsals of *Similicaudipteryx* bear pleurocoels, while in *C. zoui* and *C. dongi* the vertebral centra do not bear pleurocoels. Although most characters of the metatarsal in *Similicaudipteryx* are similar to those in *C. zoui* and *C. dongi*, the ratio of the fourth relative to the third length is smaller than in *Caudipteryx* (0.84 in *Similicaudipteryx*, 0.95 in *C. zoui* and 0.94 in *C. dongi*). Although the shape of the ilium is similar to that of *Caudipteryx*, the length of the ilium relative to the sacrum is longer than that of *C. zoui* and *C. dongi*. The ratio of pubis to ilium length is 1.46, larger than in *Caudipteryx* (1.08 in *C. zoui* and 1.04 in *C. dongi*). The ratio of the acetabulum to ilium length is about 0.23, larger than in *Caudipteryx* (0.21 in *C. zoui* and 0.20 in *C. dongi*), the ratio of acetabulum to ilium length is less than 0.11 in bird (Chiappe, 1996) (Table 2). The postacetabular portion of the ilium is longer than the preacetabular one; in dromaeosaurids and *Caudipteryx* the preacetabular portion of the ilium is as long as the postacetabular portion; in early birds the preacetabular portion is longer

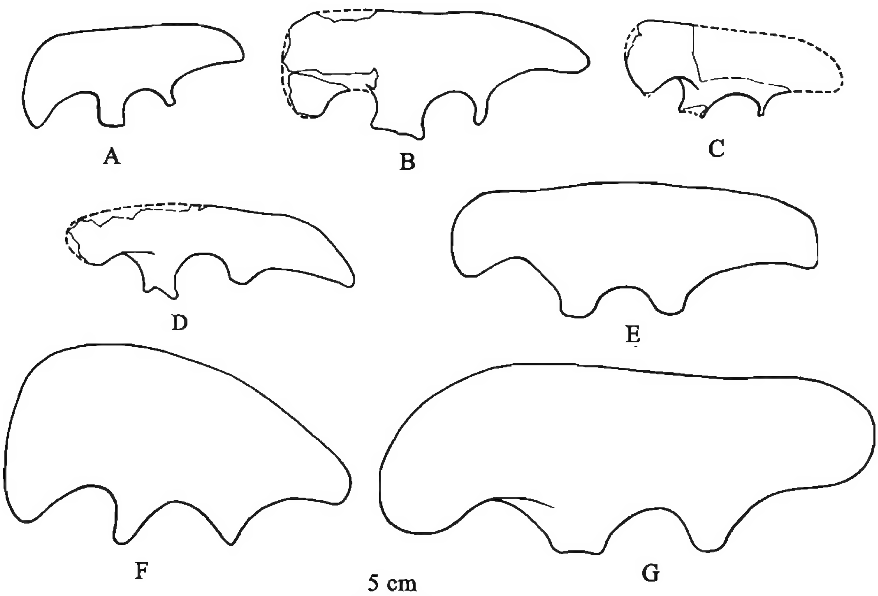

Fig. 8　Left ilia of oviraptorosaurids and a dromaeosaurid after Zhou & Wang (2000), Makovicky & Sues (1998), and Barsbold et al. (2000)
A. *Caudipteryx zoui*; B. *Microvenator celer*; C. *Similicaudiptery yixianensis*; D. a dromaeosaurid; E. *Ingenia yanshini*; F. *Oviraptor mongoliensis*; G. *Nomingia gobiensis*

than the postacetabular one. The pubic symphysis is long and the ratio of the pubic symphysis to pubis length is 0.57; in *Caudipteryx* the pubic symphysis is about half the length of the pubis (Zhou et al., 2000; Dyke and Norell, 2005), and in *Archaeopteryx* and *Confuciusornis* it is only about one third of the length of the pubis. In more advanced birds such as *Cathayornis* the pubic symphysis is even shorter. *Similicaudipteryx* is from the Jiufotang Formation, which overlies the *Caudipteryx*-bearing Yixian Formation. Based on the peculiar characters in *Similicaudipteryx*, we propose to erect a new genus: *Similicaudipteryx* gen. nov., currently including only *Similicaudipteryx yixianensis* gen. et sp. nov.

Table 2　Relative proportions of elements in relevant avian and non-avian theropods

Elements	Drom	Tro	Mic	Cx	Ax	Con	Nom	V 12556
Acetabulum/Ilium	0.22	—	0.26	0.21	0.09 *	0.1 *	0.15	0.23
Tibia/Femur	1.1 ~ 1.4	1.1 ~ 1.2	1.2	1.3	1.4	1.1	1.2	1.1
Pubis/Ilium	1.20	—	1.13	1.08	1.31 *	0.96	0.95	1.46

* denotes estimated value according to the figures. Some data are quoted from Ji et al. (1998), Makovicky & Sues (1998), and Barsbold et al. (2000). Abbreviations: Ax. *Archaeopteryx*; Con. *Confuciusornis*; Cx. *Caudipteryx zoui*; Drom. a dromaeosaurid; Mic. *Microvenator celer*; Nom. *Nomingia gobiensis*; Tro. Troodontids.

There are 5 fused sacrals in *Similicaudipteryx* as in most non-avian theropods such as *C. zoui* and the most primitive bird *Archaeopteryx*. Adding vertebrae to sacrum is not necessarily always a size-related pattern, the increased number of fused sacral vertebrae should be a derived character. So far, all known non-avian theropod dinosaurs have fewer than 8 sacral vertebrae in the synsacrum, but in birds, all except primitive birds (5 in *Archaeopteryx*, 6 in *Jeholornis*, 7

in *Confuciusornis* and *Sapeornis*) have at least 8 sacrals (e. g. 8 in *Cathayornis*). *Similicaudipteryx* possesses the character of primitive non-avian theropods based on the number of sacrals.

The first pygostyle in dinosaurs was reported in *Nomingia gobiensis* (Barsbold et al., 2000), and *Similicaudipteryx* represents non-avian theropod specimen with a pygostyle. Many characters in *Similicaudipteryx* are different from in *N. gobiensis*, such as the shape and size of the ilium (Fig. 8), the number of fused caudals (2 in *Similicaudipteryx* compared to 5 in *N. gobiensis*), the ratios of the pubis to ilium length, the femur to ilium length and the tibia to femur length (Table 2). In *Caudipteryx*, the terminal vertebrae are unfused, they seem to form a stiffened rod. The pygostyle may be indicative of a fan of elongated tail feathers (rectrices) (Barsbold et al., 2000). The pygostyle is absent in some primitive birds such as *Archaeopteryx*, *Rahonavis* and *Jeholornis*. The presence of a pygostyle in *Similicaudipteryx* indicates again that pygostyle-like structures could have evolved independently in theropod evolution.

It was proposed that the hallux of the foot is reversed in *Caudipteryx* (Ji et al., 1998; Zhou and Wang, 2000). But this cannot be confirmed by our own observation and the "reversed hallux" in *Caudipteryx* could be a preserved artifact. In *Similicaudipteryx* the hallux was not reversed as in dromaeosaurids, oviraptorids and other theropods. Therefore, so far, the full reversal of the hallux is only found within birds (Zhou and Zhang, 2006).

Similicaudipteryx possesses a suite of primitive characters such as 5 fused sacrals and long pubic symphysis; it also possesses advanced characters such as a pygostyle. This indicates that there existed mosaic evolution in Oviraptorosauia. Although most workers suggested that oviraptorosaurs have a relatively distant relationship to avians (Ji et al., 1998; Sereno, 1999; Zhou et al., 2000), some recent work suggested that oviraptorosaurs are close relatives of birds or are even secondarily flightless birds (Feduccia, 1999; Maryańska et al., 2002; Lü, 2002). According to previous work, the Caudipteridae is a basal group within Oviraptorosauria. Like *Caudipteryx* the shortened tail, the compact metatarsals and the lightly built body are also consistent with the general conclusion about the habit of *Similicaudipteryx* being a fast cursorial animal.

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References

Barsbold R, Currie P J, Myhrvold N P et al., 2000. A pygostyle from a non-avian theropod. Nature, **403**:135

Barsbold R, Osmólska H, 1990. Ornithomimosauria. In: Weishampel D B, Dodson P, Osmólska H eds. The Dinosauria. Berkeley: California University Press. 225–244

Barsbold R, Osmólska H, Watabe M et al., 2000. A new oviraptorosaur (Dinosauria, Theropoda) from Mongolia: the first dinosaur with a pygostyle. Acta Palaeont Pol, **45**(2): 97–106

Chiappe L M, 1996. Late Cretaceous birds of southern South America: anatomy and systematics of Enantiomithine and *Patagoptery deferrariisi*. Münchner Geowiss Abh Reihe A, **30**: 203–244

Clark J M, Norell M A, Makovicky P, 1999. An oviraptorid skeleton from the Late Cretaceous of Ukhaa Tolgod, Mongolia, preserved in an avianlike brooding position over an oviraptorid nest. Am Mus Novit, (3265): 1–36

Currie P J, 1990. Elmisauridae. In: Weishampel D B, Dodson P, Osmólska H eds. The Dinosauria. Berkeley: California University Press. 245–248

Dyke G J, Norell M A, 2005. *Caudipteryx* as a non-avialan theropod rather than a flightless bird. Acta Palaeont Pol, **50**(1): 101–116

Feduccia A, 1999. The Origin and Evolution of Birds. New Haven: Yale University Press. 1–466

He H Y, Wang X L, Zhou Z H et al., 2004. Timing of the Jiufotang Formation (Jehol Group) in Liaoning, northeastern China and its implications. Geophys Res Lett, **31**: L12605 doi: 10.1029/2004GL019790

Hou L H, Zhou Z M, Martin L D et al., 1995. A beaked bird from the Jurassic of China. Nature, **377**: 616–618

Ji Q, Currie P J, Norell M A et al., 1998. Two feathered dinosaurs from northeastern China. Nature, **393**: 753–761

Lü J C, 2002. A new oviraptorosaurid (Theropoda: Oviraptorosauria) from the Late Cretaceous of southern China. J Vert Paleont, **22**(4): 871–875

Makovicky P J, Sues H D, 1998. Anatomy and phylogenetic relationships of the theropod dinosaur *Microvenator celer* from the Lower Cretaceous of Montana. Am Mus Novit, (3240): 1–27

Martin L D, Zhou Z H, Hou L H et al., 1998. *Confuciusornis sanctus* compared to *Archaeopteryx lithographica*. Naturwissenschaften, **85**: 286–289

Maryańska T, Osmólska H, Wolsan M, 2002. Avialan status for Oviraptorosauria. Acta Palaeont Pol, **47**(1): 97–116

Norell M A, Makovicky P, 1997. Important features of the dromaeosaur skeleton: information from a new specimen. Am Mus Novit, (3215): 1–28

Osmólska H, Barsbold R, 1990. Troodontidae. In: Weishampel D B, Dodson P, Osmólska H eds. The Dinosauria. Berkeley: California University Press. 259–268

Ostrom J H, 1976. *Archaeopteryx* and the origin of birds. Biol J Linn Soc, **8**: 91–182

Ostrom J H, 1990. Dromaeosauridae. In: Weishampel D B, Dodson P, Osmólska H eds. The Dinosauria. Berkeley: California University Press. 269–279

Sereno C P, 1999. The evolution of dinosaurs. Science, **284**: 2137–2147

Wang X L (汪筱林), Wang Y Q (王元青), Zhou Z H (周忠和) et al., 2000. Vertebrate faunas and biostratigraphy of the Jehol Group in western Liaoning, China. Vert PalAsiat (古脊椎动物学报), **38**(supp): 40–63

Zhou Z H (周忠和), Wang X L (汪筱林), 2000. A new species of *Caudipteryx* from the Yixian Formation of Liaoning, northeast China. Vert PalAsiat (古脊椎动物学报), **38**(2): 111–127

Zhou Z H (周忠和), Wang X L (汪筱林), Zhang F C (张福成) et al., 2000. Important features of *Caudipteryx* — evidence from two nearly complete new specimens. Vert PalAsiat (古脊椎动物学报), **38**(4): 241–254

Zhou Z H (周忠和), Zhang F C (张福成), 2006. Mesozoic birds of China—a synoptic review. Vert PalAsiat (古脊椎动物学报), **44** (1): 74–98